AGRICULTURAL LIVELIHOODS AND CLIMATE CHANGE: EMPLOYING THE LIVELIHOOD VULNERABILITY INDEX IN BLUEFIELDS, JAMAICA

A Thesis

by

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ABSTRACT

The purpose of this quantitative study was to examine agricultural livelihood vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the Livelihoods Vulnerability Index (LVI). Additionally, this study sought to examine relationships between selected characteristics of adopter innovativeness and farmer vulnerability level. Random sampling was used to select participants (N=52). Personal interviews were conducted with farmers using an instrument consisting of LVI components representing livelihood strategies, natural and physical assets, socio-demographic profile, social networks, water issues, food issues, and natural disasters and climate variability. The instrument also contained questions related to selected characteristics of adopter innovativeness: years of farming experience, relative income, farm size, access to credit, contact with extension services, distance to market, and head of household age. LVI data were aggregated using an indexing approach to create scores for comparison across vulnerability components.

The study showed farmers in Bluefields have the greatest amount of vulnerability in the area of social networks and water issues. Low numbers of farmers owned their land, had contact with extension services, or used irrigation. Most farmers reported having problems with access to seeds and planting material, depended on their farms for food, and experienced frequent crop failure. Only one adopter innovativeness characteristic was significantly correlated to farmer vulnerability scores. A moderate negative association was observed between perceived relative income and farmer vulnerability.

Farmers in Bluefields are vulnerable to climate change. Development organizations and local change agents should target the areas of greatest vulnerability illuminated by this study. Vulnerability and its contributing factors (exposure, sensitivity, and adaptive capacity) should be reassessed with the LVI and other methods to monitor changes in Bluefields over time.

DEDICATION

This document is dedicated to the citizens of Bluefields in the parish of Westmoreland, Jamaica and especially to the men and women of the Westmoreland Organic Farmers Society Ltd. Living and working with you for two years was one of the most rewarding experiences of my life. You have enriched me as a person, as a researcher, and as an international development professional. Continue striving to improve your livelihood prospects and seek innovative ways to adapt to changing agricultural conditions in Bluefields.

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NOMENCLATURE

CIA	Central Intelligence Agency
FAO	Food and Agriculture Organization of the United Nations
IPCC	Inter-governmental Panel on Climate Change
LVI	Livelihood Vulnerability Index
MCDA	Multicriteria Decision Analysis
NGOs	Non-governmental Organizations
PRA	Participatory Rural Appraisal
PVA	Participatory Vulnerability Assessment
RADA	Rural Agricultural Development Authority
SDC	Social Development Commission
STATIN	Statistical Institute of Jamaica

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CHAPTER I

INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) has indicated climate is changing in the Caribbean basin (Mimura et al., 2007; Nurse et al., 2014). Precipitation data and the perceptions of Jamaican farmers reinforce this conclusion (Gamble et al., 2010). Adaptation to long-term changes in weather has been important to the Government of Jamaica and was identified as a priority of international development assistance organizations (Hutchinson, 2012).

COUNTRY PROFILE

Jamaica is an island nation with an estimated population of 2.7 million people (The World Bank, 2014). While Jamaica is considered an upper middle-income country with $14.8 billion in gross domestic product (GDP) (The World Bank, 2014), the country also ranks in the top 20% in the world for income inequality (Central Intelligence Agency [CIA], 2014). The agriculture sector contributes 6.8% of GDP and employs 17% of the population (CIA, 2014). Jamaica's unemployment rate in 2013 was 16.3%, ranking 146th in the world (CIA, 2014).

The Ministry of Agriculture and its national extension service, the Rural Agricultural Development Authority (RADA), serves Jamaican farmers (RADA, 2014). There is a RADA office in each parish with agricultural extension officers engaged in technical training, field services, assisting with production and marketing challenges, and improving social services and home economics (RADA, 2014). The Government of

Jamaica (2013) intends to improve RADA's ability to provide extension services needed to overcome many agriculture sector challenges.

Total food production per agricultural worker increased nearly 23% since 1997, however the percent of the labor force in agriculture declined from 21.6% in 1998 to 16.53% in 2013 (The Statistics Division of the FAO [FAOSTAT], 2014). Total arable land declined by 25% from 1996-2011 (FAOSTAT, 2014). Additionally, freshwater availability per capita is down nearly 10% since 1996 (FAOSTAT, 2014). These and other factors contribute to Jamaica's large food trade deficits (FAOSTAT, 2014).

COMMUNITY PROFILE

In Bluefields, Jamaica, more than 42% of males and almost 24% of females were employed in the agriculture and fisheries sector in 2012 (SDC, 2012), which is much higher than the national average (FAOSTAT, 2014). Agriculture sector growth is an especially important contributor to economic development in low-income communities like Bluefields (Barrett, 2011). Important economic contributions from agriculture sector growth are increased income for a large portion of the population, reduced local food prices, and increased demand for goods and services from related sectors (Barrett, 2011). Generating farm income growth in Bluefields will require an understanding of current conditions. Additionally, a better understanding of producers' vulnerability context and adaptive capacities should be established to assist farmers and service providers in adapting to climate change (Reid et al., 2007).

CLIMATE CHANGE AND LIVELIHOOD VULNERABILITY RESEARCH

CARIBSAVE, a non-profit organization headquartered in Barbados, conducted community-based vulnerability assessments (CARIBSAVE, 2012) in multiple Caribbean countries including Bluefields, Jamaica, the location of this study. The approach used by CARIBSAVE applied a community-based vulnerability assessment (CBVA) framework developed by Smit and Wandel (2006), which employed ethnographic methods such as semi-structured interviews, participant observation, and focus groups. CARIBSAVE (2012) research results were analyzed in tandem with climate science modeling to improve understanding of potential vulnerabilities and exposure sensitivities, as well as community specific adaption options that ought to be proposed. CARIBSAVE plans to publish the results of their CBVA studies.

This thesis study employed the quantitative Livelihoods Vulnerability Index (LVI) approach as adapted by Hahn, Riederer, and Foster (2009), Campbell (2013), and Shah, Bansha Dulal, Johnson, and Baptiste (2013). LVI is a pragmatic approach used to monitor vulnerability in data-scarce regions and provide baselines for comparison between communities and changes over time (Hahn et al., 2009). This study also used known characteristics of adopter innovativeness in developing countries to examine correlations with farmer vulnerability in Bluefields. These characteristics included years of farming experience, farm size, access to credit, contact with extension services, years of education, distance to market, and head of household age (Abdulai & Huffman, 2005).

Campbell, Barker, and McGregor (2011) determined farmers in St. Elizabeth, Jamaica perceived changes in climate, including increased rainfall variability and changing seasonal precipitation patterns. Jamaican farmers have developed coping strategies to respond to droughts caused by climatic change (Campbell et al., 2011). However, Cooper et al. (2008) argued that there is more sustainability in adaptive strategies than in coping strategies. Improved ability to adapt reduces vulnerability (Smit & Wandel, 2006).

Caribbean smallholder farmers were among the most sensitive to projected effects of climate change (McGregor, Barker, & Campbell, 2009). Depending on their level of vulnerability, smallholder farmers may be in need of adopting viable innovations as part of a longer-term strategy to adapt to climate change. One of the generalizations in Rogers' (2003) seminal work, *Diffusion of Innovations*, was "Change agents' success in securing the adoption of innovations by clients is positively related to the degree to which a diffusion program is compatible with clients' needs" (p. 375). Rogers (2003) also offered that change agents ought to be cognizant about farmers' needs and design their change programs accordingly. Therefore, understanding the vulnerability of agricultural livelihoods in Bluefields will contribute to change agents' ability to assist the diffusion of adaptive technology.

This study applied a questionnaire to quantify a composite score for components of the Livelihood Vulnerability Index (Hahn et al., 2009). Data were aggregated to determine index scores for vulnerability contributing factors determined by the IPCC: exposure, sensitivity, and adaptive capacity (McCarthy, Canziani, Leary, Dokken, &

White, 2001). Results provided information to support the work of agricultural development and extension personnel in Jamaica. Further, the results have created a baseline of data for future studies on vulnerability in Bluefields, Jamaica.

Recommendations for future research were made in the *Summary and Conclusions* section. While the LVI approach is an effective tool for assessing livelihood vulnerability in communities where little data is available (Hahn et al., 2009), the instrument and methods of this and prior LVI studies can be improved. It will be important to increase the internal reliability of the LVI to allow for more generalizable results. Future research should use qualitative methods to ensure that theory-driven risk factors are locally relevant and to identify additional risk factors for the community of interest. More research will also need to be done to fill literature gaps between livelihood vulnerability and adopter innovativeness because this study found inconclusive and non-generalizable results.

Factors that presented the greatest degree of vulnerability to Bluefields' farmers were in the areas of social networks and water issues. The farmers in this study would benefit from increased participation in community groups and linkages to persons outside of the community. As climate change causes precipitation levels to decline and rainfall variability to increases, this study showed farmers will need to increase their water harvesting capacity and use of irrigation technology. Results also showed relative income was associated with lower overall vulnerability, indicating a need to increase the productivity and profitability of agriculture in Bluefields.

CHAPTER II

LITERATURE REVIEW

CLIMATE CHANGE AND VULNERABILITY

The Initial National Communication of Jamaica (2000) to the United Nations Framework Convention on Climate Change described Jamaica's rainfall as bimodal with the highest precipitation falling in May and October and intermediate lows in March and July. The same report stated the island's rain varies monthly, annually, and spatially and that annual average rainfall declined from about 2,050 mm per year in 1960 to about 1,700 mm per year in 1998 (Initial National Communication, 2000). This trend is expected to continue and according to the IPCC Fourth and Fifth Assessment Reports (Mimura et al., 2007; Nurse et al., 2014), Caribbean islands will experience more occurrences of drought as a result of climate change. Average annual temperature in Jamaica could increase by as much as 1 – 3°C by the 2080s (CARIBSAVE, 2013). Chen, Taylor, Stephenson and Batchelor predicted that rainfall in Jamaica might decrease by as much as 10% by the year 2050 (as cited in Selvaraju et al., 2013). These changes would make Caribbean farmers more vulnerable as precipitation decreases and rainfall variability increases (McGregor et al., 2009). There has been ample research on historical and predicted climatic exposure risks for Jamaica and the Caribbean (Gamble et al., 2010; Initial National Communications, 2000; McCarthy et al., 2001; Mimura et al., 2007; Nurse et al., 2014).

Adaptation is a response meant to reduce vulnerability (Smit & Wandel, 2006). Vulnerability is defined as "the degree to which a system or unit (such as a human group or place) is likely to experience harm due to exposure to perturbations or stresses" (Kasperson, Kasperson, & Turner, 2005, p. 249). This definition encompassed the internal and external components of vulnerability expressed by the IPCC and represented elsewhere in the literature (Brooks, 2003; Chambers, 1989; Turner et al., 2003). The IPCC definition of vulnerability included the components *adaptive capacity* (internal) as well as *exposure* and *sensitivity* (external) (McCarthy et al., 2001). Climate change vulnerability assessments recently incorporated these IPCC vulnerability components (Hahn et al., 2009; Campbell, 2013, Shah et al., 2013).

The ability of persons, regions, or systems to adjust to potential disturbances, capitalize on opportunities, or respond to effects of climate change defines adaptive capacity (Ebi, Kovats, & Menne, 2006). Exposure and sensitivity are viewed as interrelated factors of vulnerability (Reid et al., 2007; Smit & Wandel, 2006). Smit and Wandel (2006) posed exposure and sensitivity as the "conditions or risks a community may be facing" (p. 289). Kasperson et al. (2005) defined exposure as "the contact between a system and a perturbation or stress" (p. 253). Sensitivity is explained as "the extent to which a system or its components is likely to experience harm, and the magnitude of that harm, due to exposure to perturbations or stresses" (Kasperson et al., 2005, p. 253).

Recent research (Campbell et al., 2011; Gamble et al., 2010) explained adaptive capacity components of vulnerability such as coping and adaptation strategies of farmers in St. Elizabeth, Jamaica. Campbell et al. (2011) paraphrased the coping strategies identified as planting methods, moisture-loss reduction, during-drought mitigation, and recovery. Farmers who employed these coping strategies were considered to be more resilient (Campbell et al., 2011), a term that can be used as an antonym for vulnerability (Adger, 2000). However, coping is a response to the problems of today, adaptive capacity is having the means today to cope with future climate change (Ebi et al., 2006).

Sea level rise, increasingly variable rainfall, severe weather events, drought, and flooding are stressors that will adversely affect agriculture in coastal communities (Nurse et al., 2014). Given calls for farmer-level research on climate adaptation (Smit & Wandel, 2006; Reid et al., 2007), more agriculture-specific studies on vulnerability and adaptation are warranted in Jamaica. Effective solutions for adapting to climate change must be community-based (Beckford, Barker, & Bailey, 2007). Hahn et al. (2009) posited that generating more primary vulnerability data at the community-level is beneficial for policy makers and further climate change adaptation research.

ASSESSING VULNERABILITY

Several studies have assessed the vulnerability of systems to climate change (Fussel & Klein 2006; McCarthy et al., 2001). These studies are important because vulnerability must be understood before planned adaptation is undertaken (Smit & Wandel, 2006). Turner et al. (2003) offered a comprehensive framework that presented vulnerability as a function of many human and environmental factors in a complex system of different processes and scales. Given this complexity, Smit and Wandel (2006) developed a participatory assessment approach as a mode for identifying functional adaptation strategies at the community level. With this approach, researchers used qualitative techniques to identify risks, how they were managed, and what limited participants' abilities to choose. Another approach, implemented by Hahn et al. (2009), was to quantify components of exposure, sensitivity, and adaptive capacity using a Livelihoods Vulnerability Index (LVI).

The LVI approach "uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts" (Hahn et al., 2009, p. 75). The primary components the original LVI used to assess livelihood vulnerability were (a) socio-demographic profile; (b) livelihood strategies; (c) health; (d) social networks; (e) food; (f) water; and (g) natural disasters and climate variability (Hahn et al., 2009). The Hahn et al. (2009) study took this vulnerability framework a step further by determining which secondary components contributed to what the IPCC identified as the three components of climate change vulnerability: exposure, sensitivity, and adaptive capacity.

In Campbell's (2013) LVI study, food imports and natural and physical assets were added as additional components while health factors were not assessed. This study is primarily modeled after the Campbell (2013) LVI framework with the exception of food imports (Table 1). According to Campbell (personal communication, June 3, 2014), food imports are a vulnerability factor in St. Elizabeth, Jamaica because the farmers there were largely engaged in commercial farming. Primarily engaged in subsistence agriculture, farmers in Bluefields have little participation in markets where competition with imported food exists.

Table 1

Livelihood Vulnerability Index: Primary and Secondary Components Used to Assess Vulnerability of Agricultural Livelihoods in Bluefields, Jamaica

LVI-IPCC Contributing Factor	LVI Primary Components	LVI Secondary components
Adaptive Capacity	Socio-demographic profile	Percent of female-headed households
		Percent of household heads with limited schooling
		Percent of households with more than four members
		Dependency ratio
	Livelihood strategies	Percent of households in which no member has off-farm employment
		Average agricultural livelihood diversification (range: 0.2 – 1.0)
		Percent of households dependent solely on agriculture as a source of income
		Income diversification index (range: 0 – 1) (Inverse of number of alternative income sources)
	Social networks	Percent of farmers who operate independently
		Percent of households lacking access to assistance from outside community
		Percent of households without any member in any community group or organization
		Average receive:give assistance ratio
		Percent of households receiving remittances
	Natural & physical assets	Percent of farmers not owning farmland
		Number of farm plots (inverse)
		Percent of farmers not having access to enough farmland
		Farm technology usage (inverse)
Sensitivity	Water Issues	Percent of households reporting not having adequate water available for farming
		Percent of households that do not practice water harvesting on their farms
		Percent of households that buy water for their farms
		Percent of farmers primarily dependent on rainfall
	Food	Percent of households dependent on farm for food
		Percent of farmers having trouble obtaining planting material
		Percent of farmers experiencing at least 1 month of food insecurity per year
		Average crop diversity index (diversity index = 1/(n+1)
Exposure	Natural disasters & climate variability	Percent of farmers with four or more production failures in the last 10 years
		Percent of farmers who do not practice drought mitigation
		Percent of farmers taking more than six months to restore production levels
		Percent of farmers not receiving early warning information for drought
		Percent of farmers who have not received assistance from RADA after a weather-related crop failure
		Mean standard deviation of the average daily maximum temperature by month
		Mean standard deviation of the average daily minimum temperature by month
		Mean standard deviation of average precipitation by month

In the LVI-IPCC framework, the primary components *natural disasters and climate variability* contributed to exposure, *food issues* and *water issues* contributed to sensitivity, and *socio-demographic profile*, *livelihood strategies*, *natural and physical assets*, and *social networks* contributed to adaptive capacity (Campbell, 2013).

Depicted in Figure 1 is the theoretical framework applied by the LVI approach in this study.

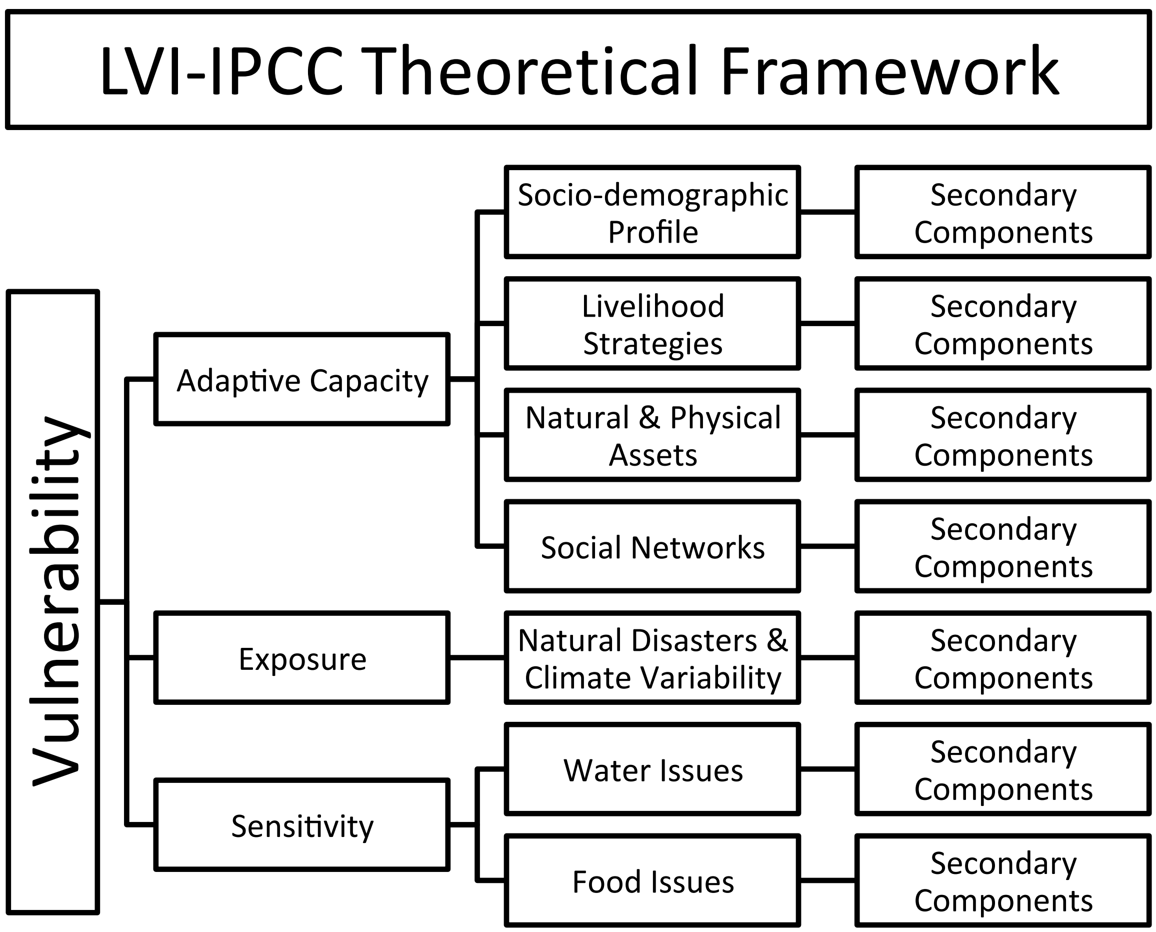

Figure 1. The *LVI-IPCC Theoretical Framework Diagram* depicts how LVI Secondary Components (far right) relate to Primary Components (second from right) that determine scores for LVI-IPCC Contributing factors (second from left), which make up the overall LVI-IPCC Vulnerability (left) for the study area.

In a collaborative effort between researchers at CARE-Mozambique and Emory University, the LVI framework was used to compare impacts of climate change on two districts in Mozambique (Hahn et al., 2009). The Campbell (2013) study also employed the LVI framework in four communities in St. Elizabeth, Jamaica. St. Elizabeth is adjacent to Westmoreland parish, where this thesis study was conducted. Unlike the Campbell (2013) study, the scope of this study precluded the researcher from conducting focus groups and other qualitative approaches to assess the relevance of the factors used. However, the researcher lived in Bluefields for more than 20 months before collecting data. The time in the community allowed the researcher to gain insights necessary to observe and understand the conditions affecting the population of interest (Mack et al., 2005).

Hahn et al. (2009) conceded it is difficult to establish validity with an indexing approach that uses varied indicators. Conversely, Vincent (2007) argued that regardless of the uncertainty surrounding the measurement of vulnerability, the need for empirical assessment is a necessity for informed policy making. The LVI framework approach is one such form of empirical assessment.

ADOPTER INNOVATIVENESS AND VULNERABILITY

Institutions in Jamaica are developing policies aimed at improving climate change adaptation in the agriculture sector (Selvaraju et al., 2013). Inducing farm-level adoption of technology can be enhanced by targeting specific groups of people based on attributes associated with innovativeness (Rogers, 2003). Generally speaking, Rogers (2003) determined adopters are distributed normally and consist of five distinct groups in a population. These groups and their prevalence in a population are as follows (Rogers, 2003): *innovators* (2.5%), *early adopters* (13.5%), *early majority* (34%), *late majority* (34%), and *laggards* (2.5%). Innovators are the first to adopt whereas laggards are last or never adopt. Based on this segmentation, policy makers and change agents can improve technological diffusion by targeting their activities based on the known attributes and interactions of adopter groups (Rogers, 2003).

The five distinct groups used for audience segmentation described in the previous paragraph have been applied in developed countries like the United States (Rogers, 2003). However, recent studies determined this theory does not always translate well to farmers in developing countries (Abdulai & Huffman, 2005; Smith & Findeis, 2013).

Rather than try to identify adopter segmentation in Bluefields, this study examined the relationship between vulnerability scores and selected characteristics of adopter innovativeness that have previously been studied in a developing country context. These adopter innovativeness characteristics include years of farming experience, farm size, access to credit, contact with extension services, education, distance to market, and head of household age (Abdulai & Huffman, 2005). Rogers (2003) posed innovativeness as, “the degree to which an individual is relatively earlier in adopting new ideas than other members of a system” (p. 22). Technological adoption is recognized as a way to increase adaptive capacity (Smit & Wandel, 2006), thus reducing vulnerability. Determining correlations between these characteristics of adopter innovativeness and levels of livelihood vulnerability may help determine if the LVI approach can be used to advance diffusion research in the context of climate change.

In summary, the LVI approach was developed because of the need to understand impacts of climate change on communities. The intent of the LVI-IPCC framework is to assess the exposure, sensitivity, and adaptive capacity of a community and its level of risk (Hahn et al., 2009). Rogers (2003) suggested that change agents ought to be cognizant about farmers' needs and create their change programs accordingly. This study may contribute to increased cognizance of farmer needs relative to climate change in Bluefields, Jamaica. Greater understanding of the relationships between adopter innovativeness and vulnerability provides new insights into how diffusion of innovation theory may be used to reduce agricultural livelihood vulnerability in the face of climatic change.

CHAPTER III

METHODS

The purpose of this study was to examine farmer vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the Livelihoods Vulnerability Index (Hahn et al., 2009) and to examine relationships between selected characteristics of adopter innovativeness and farmer vulnerability level. The research objectives were to:

1. Assess factors affecting livelihood vulnerability to climate change of farmers in Bluefields, Westmoreland, Jamaica;
2. Determine farmers' level of adaptive capacity, exposure, and sensitivity to climate change through the LVI-IPCC method; and,
3. Determine relationships between livelihood vulnerability of farmers and selected characteristics of adopter innovativeness.

DESIGN

This study used a quantitative design and incorporated a questionnaire administered through personal interview (Ary et al., 2010). Personally administering the questionnaire was an important design feature because it allowed the researcher to observe the respondent and surroundings, control the order in which questions were asked, and increase the response rate (Ary et al., 2010). Quantitative data were necessary to calculate the Livelihood Vulnerability Index and measure relationships between variables in the sample using statistical tests.

POPULATION AND SAMPLE

Bluefields is situated along the southwest coast of Jamaica. According to Jamaica's Social Development Commission (SDC, 2012), the 2008 estimated population of Bluefields was 4,708 persons living in 1,121 households. Women were heads of just over one-half (50.9%) of households, which is higher than the national average of 46.6% (SDC, 2012). Nearly 58% of the Bluefields' population was female (SDC, 2012). In 2008, 72% of the Bluefields' labor force was at least part-time employed (SDC, 2012). Just over 42% of males and nearly 24% of females were employed in the agriculture and fisheries sector (SDC, 2012). Nearly all residents were of Afro-Caribbean descent; about 31% of the population was under the age of 15 and 66% below 30 years of age (SDC, 2012).

The sample frame (N = 112) included farmers in the sub-districts of Belmont, Bluefields, Mount Airy, Mount Edgecombe, Robins River, and Shafston, which make up the community of Bluefields, Westmoreland, Jamaica. It was difficult to identify exactly how many farm households were in the target population; therefore, the sampling frame was identified using a list of registered producers acquired from the Ministry of Agriculture (RADA, 2013) and input from local farmers who identified additional farmers in the community. Given time and resource constraints a census was not conducted. Random sampling (Ary et al., 2010) was used. Participants were selected using Microsoft Excel software from a master list of Bluefields' farmers compiled from the RADA list and names provided by several members of the local farming cooperative.

INSTRUMENTATION

Indicators used in the LVI questionnaire were predominantly theory-driven (Vincent, 2007), with the exception of data-driven meteorological information such as historical rainfall and temperature. Most questions were worded to elicit categorical responses, including Male/Female, Yes/No, or indicating a range of responses (e.g., 1…4). The open-ended questions (i.e., types of crops grown) allowed participants to list one or multiple items.

The LVI for this study employed a balanced weighted average method (Sullivan, Meigh, & Fediw, 2002). The LVI consisted of seven primary components and 34 secondary components. Table 2 depicts these primary and secondary components. Table 2 also shows the source of the secondary component and whether or not it has been adapted from its original form. Questions used in the instrument are also shown in Table 2, as are explanatory notes as needed.

All secondary components contributed to the overall LVI equally; regardless of the fact primary components had different numbers of contributing secondary components (Hahn et al., 2009). It was necessary to standardize each secondary component as an index because each was assessed on a different scale (Hahn et al., 2009).

The formula (Hahn et al., 2009) used to standardize each indicator was:

$$\text{index}_{s_d} = \frac{s_d - s_{min}}{s_{max} - s_{min}} \tag{1}$$

where "s_d is the original sub-component for district d, and s_{min} and s_{max} are the minimum and maximum values, respectively, for each sub-component…" (Hahn et al., 2009, p.

Table 2

Primary Components, Secondary Components, Survey Questions, and Explanatory Notes of the Livelihood Vulnerability Index (LVI) Developed for Bluefields, Jamaica

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
Socio-demographic Profile				
1. % of female-headed households	Hahn et al. (2009)	Percent of households where primary farming decision maker is female	Who is the head of this household?	
2. % of household heads with limited schooling	Adapted from Hahn et al. (2009)	Percent of farmers who did not complete schooling beyond the 9th grade	What is the last grade in school that you completed?	Modified to differentiate between farmers who had completed the 9th grade at the local All-age School
3. % of households with more than four members	Adapted from Campbell (2013)	Determined by households reporting more than four household inhabitants	How many people live in this household	Reduced from more than 5 to more than four inhabitants for this study because average household size in Westmoreland is 3 (STATIN, 2011)
4. Dependency Ratio	Hahn et al. (2009)	Ratio of household inhabitants below 15 and over 65 to those 19 to 64 years old	What are the ages of all persons living in this household?	
Livelihood strategies				
1. Absence of off-farm income	Adapted from Hahn et al. (2009)	% of households where no member has off-farm income	Do any members of this household earn income away from the farm?	Differs from Hahn et al. by including all household members rather than just family members
2. Average Agricultural Livelihood Index (range: 0.2 – 1.0)	Hahn et al. (2009)	Inverse of the number of agricultural livelihood strategies. Index = 1/(n+1)	In how many farm income activities is this household engaged?	Farmers were asked to list separate income-generating farming activities (e.g. crops, livestock, agroforestry, apiculture)

Table 2 Continued

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
3. Income diversity index	Hahn et al. (2009)	Inverse number of total household sources of income. Index = 1/(n+1)	How many sources of income does this household earn?	An inverse score was used because a higher raw score would indicate more vulnerability, not less.
4. Dependency on agricultural livelihoods	Hahn et al. (2009)	% of farmers who reported only agricultural income		Determined by summing households who reported only agricultural income
Social networks				
1. Remittance	Created for this study	% of farming households who reported receiving remittances	Do you receive remittance transfers from friends or family overseas?	According to the OECD (2012), nearly 900 thousand Jamaicans live abroad, and remittances consist of about 15% of GDP.
2. Farming Independently	Adapted from Campbell (2013)	% of farmers who do not work with other farmers in their activities	Do you work with other farmers on your farm?	
3. Out-of-Community Farming Collaboration	Adapted from Campbell (2013)	% of farmers reporting a lack of collaboration with farmers outside their community	Does anyone outside of the community help you on your farm?	Out-of-community networks are important for technology adoption decisions (Rogers, 2003) and reducing vulnerability (Smit & Wandel, 2006).
4. Receive:give ratio	Adapted from Hahn et al. (2009)	Respondents were given scores based on ability to receive and give financial assistance in emergencies: Can Receive:Can Give = 0.0; Can Receive:Cannot Give = 0.33; Cannot Receive:Can Give = 0.67; Cannot Receive:Cannot Give = 1.0	When crops fail or emergencies arise, are you able to get financial assistance from friends or family? When crops fail or emergencies arise, are you able to give financial assistance to friends or family?	*Receive:give ratio* was modified from Hahn et al. (2009) to reflect respondent's perception of his/her general ability to receive/give assistance. Also, the change was made to ensure the score reflected higher vulnerability for those who are unable to receive assistance from friends or family in emergencies

Table 2 Continued

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
5. Organizational membership	Adapted from Campbell (2013)	% of households with zero membership in community groups or organizations	Are you or any member of your household a member of a community group or organization?	
Water Issues				
1. Water for Farm	Adapted from Campbell (2013)	% of households reporting not having adequate water available for farming	Do you have problems obtaining adequate water for your farm?	Focused on water availability for the farm rather than farm and household.
2. Water Harvesting	Adapted from Campbell (2013)	% of farmers not engaging in water harvesting for their farm	Do you practice water harvesting for your farm?	Focused on water harvesting for farms rather than farm and household.
3. Water Purchasing	Adapted from Campbell (2013)	% of farmers who depend on purchased water to be able to grow their crops	Do you have to purchase water for your farm?	
4. Rainfall Dependency	Adapted from Campbell (2013)	% of farmers who consider their farm primarily dependent upon rainfall	Do you consider your farm primarily dependent on rainfall?	
Food Issues				
1. Access to planting material	Adapted from Campbell (2013)	% of farmers who report difficulty finding or affording planting material like seeds and seedlings	Are there times when you cannot find or afford planting material?	
2. Average crop diversity index	Hahn et al. (2009)	Inverse of the number of types of crops grown by the farmer: 1/(n+1)	What crops are grown by this household?	A household that grows only corn, pumpkin, and callaloo would have a Crop Diversity Index = 1/(3+1) = 0.25
3. Seed Saving	Hahn et al. (2009)	% of farmers who do not engage in seed saving	Do you save seeds to grow the next season?	

Table 2 Continued

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
4. Food Insecurity	Adapted from Hahn et al. (2009)	% of farmers who report at least one month of food insecurity per year	During a typical year, how many weeks or months does your family struggle to have enough to eat?	Interpretation of the word “struggle” can vary. The researcher helped the respondent to understand the meaning of the question using appropriate terminology when necessary.
5. Dependence on own farm for food	Hahn et al. (2009)	% of farm households dependent upon their own farms for most of their food	Where does your family get most of its food?	It is difficult to know how well respondents were able to analyze where “most” of their food comes from when so much of the Jamaican diet consists of a single item, rice, which is typically purchased.
Natural disasters & climate variability				
1. Crop failure	Adapted from Campbell (2013)	% of farmers who experienced 4 or more crop failures in the last 10 years	How many crop failures have you experienced in the past 10 years?	Farmers may interpret crop failure differently
2. Drought mitigation	Adapted from Campbell (2013)	% of farmers who do not practice any drought mitigation techniques	What do you do to protect your farm against the occurrence of drought?	
3. Drought recovery	Adapted from Campbell (2013)	% of farmers requiring 6 months or more to restore production levels after a drought event	How long does it take to bring your farm back to normal production level following a drought?	Difficult for farmers to estimate this and may be biased toward the most recent drought event
4. Drought warning	Adapted from Campbell (2013)	% of farmers who report not receiving warnings or forecasts about drought events	Do you receive warnings about drought events?	

Table 2 Continued

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
5. Post weather-related crop loss assistance	Adapted from Campbell (2013)	% of farmers who reported having never received assistance from the Rural Agricultural Development Authority (RADA) following a weather-related crop failure	Have you received assistance from RADA after a weather-related crop failure?	Most Jamaican farmers seem to use RADA as blanket terminology for the extension service and the Ministry of Agriculture.
6. Daily high temperature variation	Hahn et al. (2009)	Mean standard deviation of daily average maximum temperature by month	Meteorological Service of Jamaica data for 1996-2007	Limited to the Frome weather station located 20 kilometers from Bluefields
7. Daily low temperature variation	Hahn et al. (2009)	Mean standard deviation of the daily average minimum temperature by month	Data provided by the Meteorological Service of Jamaica for 1996-2007	Limited to the Frome weather station located 20 kilometers from Bluefields
8. Monthly rainfall variation	Hahn et al. (2009)	Mean standard deviation of average precipitation by month	Data provided by the Meteorological Service of Jamaica for 1999-2012	Limited to the Darliston weather station located 10 kilometers from Bluefields
Natural and Physical Assets				
1. Land ownership	Campbell (2013)	% of farmers not owning the land that they farm	Do you or your family own the land on which you farm?	
2. Farmland availability	Campbell (2013)	% of farmers who report not having access to additional farmland	Is there more farmland available to you?	Definition of “available” may vary depending on land tenure status

Table 2 Continued

Primary components/Secondary components	Source/Status in LVI	Explanation of secondary components	Survey question	Explanatory Notes / Edits
3. Agricultural technology use	Adapted from Campbell (2013)	Inverse of the number of the following four technologies farmers reported using: improved seeds, irrigation, fertilizer, pesticide/herbicide. Score = 1/(n+1)	Do you use seeds for improved varieties? How do you water your crops? How do you fertilize your crops? How do you control weeds and pests?	In contrast to Campbell (2013), farmers who reported using organic fertilizer or natural pest and weed control were counted the same as those who use chemical alternatives.
4. Number of farm plots	Campbell (2013)	Inverse of the number of separate farm plots used by the farmer. Score = 1/(n+1)	How many separate farm plots are you farming on?	Some respondents may have had difficulty understanding the difference between separate farm sections and plots

76). For this study, district (*d*) should be considered as representing Bluefields as a whole. Variables represented as percentages had the minimum value set at 0 and the maximum value set at 100. For indicators such as *Average crop diversity index*, a higher crude score indicated less vulnerability. In cases like this, an inverse value was calculated.

After all secondary components were standardized, each was averaged with the following equation to determine the value of each primary component:

$$M_d = \frac{\sum_{i=1}^{n} index_{s_d i}}{n} \qquad (2)$$

In this equation, M_d represented one of the seven primary components for district *d* [Socio-demographic profile (SDP), Livelihood strategies (LS), Social networks (SN), Water Issues (W), Food Issues (F), Natural disasters and climate variability (NDCV), or Natural and physical assets (NPA)]. Secondary components were represented by the variable $index_{s_d i}$, indexed by *i*, which made up each of the listed primary components, and *n* was the number of secondary components in each primary component (Hahn et al., 2009).After scores for each of the seven primary components for a district were computed, they were averaged with the following equation to determine the district-level (Bluefields) LVI:

$$LVI_d = \frac{\sum_{i=1}^{7} w_{M_i} M_{di}}{\sum_{i=1}^{7} w_{M_i}} \qquad (3)$$

or

$$LVI_d = \frac{[w_{SDP}(SDP_d)] + [w_{LS}(LS_d)] + [w_{SN}(SN_d)] + [w_W(W_d)] + [w_F(F_d)] + [w_{NDCV}(NDCV_d)] + [w_{NPA}(NPA_d)]}{w_{SDP} + w_{LS} + w_{SN} + w_W + w_F + w_{NDCV} + w_{NPA}} \qquad (4)$$

The Livelihood Vulnerability Index, LVI_d, is a product of the weighted average of the seven primary components for Bluefields. Primary component weights, w_{M_i}, were based on the number of secondary components that made up each respective primary component (Hahn et al., 2009). Weights were used to make sure all secondary components equally contributed to the overall LVI (Sullivan et al., 2002).

In order to compute the LVI-IPCC score, the primary components were categorized into the contributing factors to vulnerability (exposure, sensitivity, or adaptive capacity) in accordance with the LVI-IPCC framework (Figure 1). The final composite LVI-IPCC score for each contributing factor was calculated with the formula (Hahn et al., 2009):

$$CF_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{di}}{\sum_{i=1}^{n} w_{M_i}} \qquad (5)$$

where CF_d represents one of the IPCC-defined contributing factors to vulnerability for district *d* (Bluefields). M_{di} represented the primary components for the district *d* indexed by *i*, the weight of each major component was w_{M_i}, and *n* was the number of primary components that made up each contributing factor. After the score for each contributing factor (exposure, sensitivity, and adaptive capacity) was calculated, they were combined using this equation:

$$\text{LVI-IPCC}_d = (e_d - a_d) * s_d \qquad (6)$$

in which LVI-IPCC_d was the LVI for Bluefields as within the IPCC framework, *e* represented the score for exposure, *a* was the score for adaptive capacity, and *s* was the score for sensitivity. Before calculating a_d, the standardized scores for adaptive capacity were inversed using (1 – n). The scale for the LVI-IPCC is -1.0 to 1.0 (Hahn et al., 2009).

Additional questions were incorporated into the questionnaire survey to determine respondents' possession of known characteristics of adopter innovativeness (Abdulai & Huffman, 2005; Rogers, 2003). These characteristics included years of farming experience, access to credit, extension services contact, perceived relative income, farmer age, distance to a permanent market, and farm size. Once the raw data were standardized to a scale of 0 – 1, the mean score representing vulnerability was calculated for each farmer. These individual farmer vulnerability scores were analyzed for correlation with adopter innovativeness characteristics.

It is important to note that the average receive:give ratio used by Hahn et al. (2009) was modified for this study. For cultural reasons, the researcher did not want to ask respondents specific questions about their recent activities in giving or receiving financial assistance to friends or family as was done by Hahn et al. (2009). The researcher also wanted to avoid seasonal bias (Chambers, 1983) and, therefore, only asked if the respondent felt he or she could give or receive financial assistance, rather than if they had in the past month. The average receive:give assistance was determined by assigning a score of 0.0 to those who felt they could both give and receive financial assistance to friends or family in emergencies. A score of 0.33 was given to those who felt they could receive financial assistance, but not give. Those who felt they could not receive, but could give financial assistance were given a score of .67. Finally, those who felt they could neither give nor receive financial assistance in emergencies were given a vulnerability score of 1.0.

DATA COLLECTION

Data were collected from February through April 2014. The instrument was administered by the researcher, who was familiar to many of the farmers after living in Bluefields for 20 months prior to data collection. This familiarity encouraged farmers to be comfortable and provide more forthright answers (Rogers, 2003).

The Livelihood Vulnerability Index survey questionnaire was administered via personal interview. Prior to the interview, an information sheet with details pertaining to research participant rights was read to the respondent, signed by the interviewer, and given to the participant to keep. Once verbal consent was given by the participant, a structured questionnaire was used to collect data. Interviews lasted 30-45 minutes. Languages used include English, Jamaican Patois, or a mixture of these two languages during the interview. No personally identifiable information was collected to ensure privacy and confidentiality for participants.

DATA ANALYSIS

Descriptive statistics (frequencies, means, percentages, and standard deviations) were used to analyze and report data. Data from the questionnaire relevant to the LVI was averaged, weighted, and converted to indices using the formulas presented in the *Instrumentation* section. Bivariate correlations were calculated to identify relationships between the variables for adopter innovativeness and the individual vulnerability scores. Confidence intervals were set *a priori* at $\alpha = 0.05$.

CHAPTER IV

FINDINGS

The purpose of this study was to examine farmer vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the Livelihoods Vulnerability Index (Hahn et al., 2009) and to examine relationships between selected characteristics of adopter innovativeness and farmer vulnerability level. The research objectives fulfilling this purpose were to:

1. Assess factors affecting livelihood vulnerability to climate change of farmers in Bluefields, Westmoreland, Jamaica;
2. Determine farmers' level of adaptive capacity, exposure, and sensitivity to climate change through the LVI-IPCC method; and,
3. Determine relationships between livelihood vulnerability of farmers and selected characteristics of adopter innovativeness.

To better understand the results of this study, response rates, reliability indices, and the demographic profile are presented. A random sample of 52 farmers was drawn from the sample frame (N=112) to achieve a 95% confidence interval at 10% margin of error (Dillman, 2007). Twelve persons were either unreachable or declined to participate, giving a response rate of 77%. Cronbach's alpha scores for the instrument did not reach the threshold for reliability that would allow for generalizable results. The Cronbach's coefficient for Adaptive Capacity was $\alpha = 0.34$, for Exposure $\alpha = 0.23$, and for Sensitivity $\alpha = 0.28$. Cronbach's correlation coefficient for the selected characteristics of adopter innovativeness was $\alpha = 0.45$. The small sample size, a limited number of questions to represent each construct (primary component) in the instrument, and the extensive use of a dichotomous scale for responses limited the ability to achieve sufficient internal reliability. Therefore, these findings apply only to the sample frame in Bluefields, Jamaica.

Respondents were predominantly male (80%) and averaged 52 years of age. Most (67.5%) lived in households of four or less and had an average of 28.8 years of farming experience (Table 3). Most (47.5%) viewed their income as below the community average, while 31.5% considered their income to be average and 21% above average. Seventy percent farmed less than 2.5 acres. Fifty percent reported having access to farm credit while 35% said they had no access and 15% were unsure. It is unknown how many respondents have used credit in the past or would take out a loan if available. Half of respondents reported zero contacts with extension services, while those who had contacts less than annually, annually, and multiple times per year were 30%, 10% and 10%, respectively. The average distance to a permanent market reported by farmers was 4.99 miles.

Table 3

Demographic Profile (N=40) of Study Participants in Bluefields, Jamaica

Variable	Category	f^a	%
Head of Household Gender	Male	32	80.0
	Female	8	20.0
Farmer Age	≤ 34	2	5.0
	35-44	8	20.0
	45-54	13	32.5
	55+	17	42.5
Household Size	4 or less	27	67.5
	5 or more	13	32.5
Education Level	None	2	5.0
	All-age (1-9)	21	52.5
	Secondary (10-12)	12	30.0
	Tertiary (13+)	5	12.5

OBJECTIVE 1

The first objective was to assess factors affecting vulnerability to climate change of farmers in Bluefields, Westmoreland, Jamaica. The indexed results for the primary and secondary LVI components provided insights into the Bluefields vulnerability context. Quartiles were determined for secondary component index scores (excluding temperature and rainfall data): $Q_1 = 0.32$; $Q_2 = 0.48$; and $Q_3 = 0.66$. Table 4 shows the indexed scores for each of the three IPCC designated components of vulnerability and the indexed scores for each contributing secondary component. All scores in Table 4 were on a 0.0 to 1.0 scale and higher scores indicate greater vulnerability.

Factors in the upper-quartile of vulnerability scores (i) were (a) percent of households dependent upon their farm for food ($i = 0.88$); (b) percent of farmers who have never received assistance from RADA following a weather-related crop failure ($i =$

0.88); (c) percent of farmers dependent on rainfall (*i* = 0.87); (d) percent of farmers having trouble obtaining planting material (*i* = 0.73); (e) percent of households who do not receive remittances (*i* = 0.70); (f) percent of households reporting problems getting adequate water for farming (*i* =.70); (g) percent of farmers not owning farmland (*i* = 0.70); and (h) percent of households lacking access to farm assistance from outside community (*i* = 0.68).

Factors in the third-quartile for vulnerability include (a) average receive:give ratio (*i* = 0.64); (b) number of farm plots (*i* = 0.62); (c) percent of farmers with four or more production failures in the last 10 years (*i* = 0.62); (d) percent of household heads with less than ten years of education (*i* = 0.58); (e) average agricultural livelihood diversification index (*i* = 0.54); (f) dependency ratio (*i* = 0.54); (g) percent of households without any member in any community group or organization (*i* = 0.53); and (h) farm technology usage (*i* = 0.50).

Factors in the lower-quartile for vulnerability included (a) percent of households in which no member has off-farm employment (*i* = 0.31); (b) percent of farmers not receiving early warning information about drought (*i* = 0.28); (c) percent of households dependent solely on agriculture as a source of income (*i* = 0.28); (d) percent of households experiencing one month or more of food insecurity per year (*i* = 0.28); (e) percent of households that buy water for farming (*i* = 0.23); (f) percent of female-headed households (*i* = 0.20); (g) percent of farmers who do not engage in seed saving (*i* = 0.13); and (h) percent of farmers not having access to enough farmland (*i* = 0.05).

Table 4

Livelihood Vulnerability Index Scores for Agricultural Livelihoods in Bluefields, Jamaica

IPCC Component	Index Score[1]	Primary Component	Secondary Component	Index Score[a]
Adaptive Capacity	.46	Socio-demographic Profile	Percent of female-headed households	.20
			Percent of household heads with less than ten years of education	.58
			Percent of households with more than four members	.33
			Dependency ratio	.54
		Livelihood Strategies	Percent of households in which no member has off-farm employment	.31
			Average agricultural livelihood diversification index (range: 0.125 – 1.0)	.54
			Percent of households dependent solely on agriculture as a source of income	.28
			Income diversification index (range: 0 – 1) (Inverse of number of alternative income sources)	.32
		Social Networks	Percent of farmers who operate independently	.40
			Percent of households lacking access to assistance from outside community	.68
			Percent of households without any member in any community group or organization	.53
			Average receive:give ratio	.64
			Percent of households who do not receive remittances	.70
		Natural & Physical Assets	Percent of farmers not owning farmland	.70
			Number of farm plots (inverse)	.62
			Percent of farmers not having access to enough farmland	.05
			Farm technology usage (inverse)	.50
Sensitivity	.51	Water Issues	Percent of households reporting problems with getting adequate water for farming	.70
			Percent of households that do not practice water harvesting	.35
			Percent of households that buy water for farming	.23
			Percent of farmers primarily dependent on rainfall	.87
		Food Issues	Percent of households dependent on farm for food	.88
			Percent of farmers having trouble obtaining planting material	.73
			Average crop diversity index (diversity index = 1/(n+1)	.47
			Percent of households experiencing one month or more annual food insecurity	.28
			Percent of farmers who do not save seeds	.13
Exposure	.49	Natural Disasters & Climate Variability	Percent of farmers with four or more production failures in the last 10 years	.62
			Percent of farmers who do not practice drought mitigation	.40
			Percent of farmers taking more than six months to restore production levels	.38
			Percent of farmers not receiving early warning information about drought	.28
			Percent of farmers who never received assistance from RADA following a weather-related crop failure	.88
			Mean standard deviation of the daily average maximum temperature by month	.52
			Mean standard deviation of the daily average minimum temperature by month	.36
			Mean standard deviation of average precipitation by month	.47

Note. [a] Index Scores are on a 0.0-1.0 scale. A higher index score indicates a higher level of vulnerability.

Table 5 displays the index score for each primary component. The primary components showing the greatest amount of vulnerability were Social Networks (0.588) and Water Issues (0.537). The primary components showing the least vulnerability were Livelihood Strategies (0.361) and Socio-demographic Profile (0.411). The overall LVI score generated from the weighted averages of each primary component yielded 0.483, a number against which future LVI studies in Bluefields can be compared.

Table 5

LVI Composite Scores by Primary Component for Farmers in Bluefields, Jamaica

IPCC components	LVI Primary Components	Primary Component Index Score[a]
Exposure	Natural disaster & climate variability	.49
Adaptive capacity	Socio-demographic profile	.41
	Livelihood strategies	.36
	Social networks	.59
	Natural & physical assets	.47
Sensitivity	Food Issues	.50
	Water Issues	.54
	Bluefields Livelihood Vulnerability Index score	.48

Note. [a] Index Scores are on a 0.0 to 1.0 scale. A higher index score indicates a higher level of vulnerability.

OBJECTIVE 2

The second objective was to determine farmers' level of adaptive capacity, exposure, and sensitivity to climate change through the LVI-IPCC method. The IPCC identified three contributing factors to climate change vulnerability: a) exposure; b) adaptive capacity; and c) sensitivity (McCarthy et al., 2001). Secondary components of the LVI contributed to each of these factors were illustrated in Table 5. The weighted average of LVI secondary components was calculated to create LVI-IPCC scores as seen in Table 6.

With one exception, calculating the LVI-IPCC score entailed the same steps and equations (Eqs 1 – 3) involved in computing the overall LVI score (Hahn et al., 2009). In calculating the overall LVI score for agricultural livelihoods in Bluefields, all primary components were combined (Equation 4). However, to calculate the overall LVI-IPCC, Equation 5 was used to determine scores for each IPCC component of vulnerability. These scores for exposure, adaptive capacity, and sensitivity were then entered into Equation 6. The inverse of the adaptive capacity score was used in Equation 6 to represent the opposite of vulnerability. In other words, Equation 6 represented exposure being mitigated by adaptive capacity and then multiplied by sensitivity. This equation yielded an overall LVI-IPCC score of -0.03 for Bluefields.

Table 6

LVI-IPCC Scores for Agricultural Livelihoods in Bluefields, Jamaica

LVI-IPCC components	LVI-IPCC Score[a]
Exposure	.49
Adaptive Capacity	.54[b]
Sensitivity	.51
LVI-IPCC: [(Exposure – Adaptive Capacity) x Sensitivity]	-.03[c]

Note. [a] Scores are on a scale of 0.0 to 1.0. [b] An inverse of Adaptive Capacity is used in the calculation of overall LVI-IPCC. [c] LVI-IPCC Score is on a scale of -1.0 to 1.0, the closer to 1.0, the greater the vulnerability; the closer to -1.0, the greater the resiliency

OBJECTIVE 3

The third objective was to determine relationships between livelihood vulnerability of farmers and selected characteristics of adopter innovativeness. The data included nominal, ordinal, and interval variables. Therefore, depending on variable type, Pearson's bivariate and Spearman rho correlational tests were conducted to determine relationships between known adopter innovativeness characteristics and individual farmer vulnerability scores. Effect size was applied according to Davis (1971) who determined 0.01-0.09 to be negligible association, 0.10-0.29 was low association, 0.30-0.49 to be moderate association, 0.50-0.69 to be substantial association, and 0.70+ to be very strong association.

A significant moderate negative correlation existed between perceived relative income and individual farmer LVI scores (r_s = -.40, p = <.05). In other words, having greater income was moderately associated with having lower vulnerability to climate change in Bluefields. This negative correlation indicated an inverse association between these variables; a causal relationship was not determined. Correlations between individual farmer vulnerability scores and selected adopter innovativeness characteristics are shown in Table 7.

Table 7

Correlations between Adopter Innovativeness Characteristics and Agricultural Livelihood Vulnerability in Bluefields Jamaica

Innovativeness Characteristic	Correlation with Agricultural Livelihood Vulnerability Scores
Years of Farming Experience	0.15
Relative Income	- 0.40*
Farm Size	-0.11
Access to Credit	0.18
Extension Contact	- 0.08
Distance to Market	- 0.00
Farmer Age	0.16

Note. * $p \leq 0.05$, two-tailed.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose was to examine farmer vulnerability to climate change in Bluefields, Westmoreland, Jamaica based on the Livelihoods Vulnerability Index (Hahn et al., 2009). Additionally, this study sought to examine relationships between selected characteristics of adopter innovativeness and farmer vulnerability. The LVI measured vulnerability based on seven primary components. Social Networks ($i = 0.59$) and Water Issues ($i = 0.58$) were the primary components with the highest scores for vulnerability; Livelihood Strategies ($i = 0.36$) was the primary component with the lowest vulnerability score. Results provided insight into factors impacting on vulnerability of agricultural livelihoods in Bluefields, Jamaica and uncovered opportunities to improve the LVI approach for future research.

The eight secondary components in the upper quartile for vulnerability provide focus for policies or programs to improve resiliency of agricultural livelihoods in Bluefields. Most farmers in this study were dependent on their farms for food, which increased their risk from natural disasters and climate variability (Selvaraju et al., 2013). Additional risk is demonstrated by the finding most Bluefields farmers have never received recovery assistance following a weather-related crop failure. Efforts to increase farm incomes and provide crop insurance could reduce this risk and improve food security (Lotze-Campen & Schellnhuber, 2009).

Water is a key component of productive tropical agriculture (Rockström, Barron, & Fox, 2003). However, most Bluefields producers reported they depend on rainfall and do not have adequate water for farming. When rainfall creates conditions suitable to plant crops, farmers reported they have trouble finding or affording planting material. Agricultural credit services could allow farmers to invest in water harvesting infrastructure, drip irrigation, and planting material. However, most farmers in Bluefields did not own their land, which could be a constraint to the use of credit services (Graham & AgDarroch, 2001). Farmers with secure tenure are more likely to invest in agriculture (Burton, 2005). Therefore, potential solutions lie in creating opportunities for farmers to secure land ownership or in developing credit services for untenured farmers. Improving out-of-community social and financial connections for farmers may be difficult to target through policies or programs, but are important components of vulnerability in Bluefields to consider.

Adaptive capacity, exposure, and sensitivity are the contributing factors to vulnerability according to the IPCC (McCarthy et al., 2001). Sensitivity is the degree to which a system is likely to experience harm as a result of a stress factor (Kasperson et al., 2005). Sensitivity (0.513) was the highest LVI-IPCC score for Bluefields. Exposure is "the contact between a system and a perturbation or stress" (Kasperson et al., 2005, p. 253). Exposure risk in Bluefields was measured at 0.486. Adaptive capacity is the ability of persons or systems to adjust to potential stressors, capitalize on opportunities, or respond to consequences of climate change (Ebi et al., 2006); vulnerability for adaptive capacity in Bluefields was indexed at 0.439.

Relationships between selected adopter innovativeness characteristics and individual farmer vulnerability scores yielded largely inconclusive results. The only significant association was a moderate negative effect of relative income on individual vulnerability (r_s = -.40, p = <.05), calling into question the efficacy of the LVI approach for providing a definitive relationship between vulnerability and characteristics associated with adopter innovativeness.

PREVIOUS LVI RESEARCH

LVI studies used different primary and secondary components depending on what is appropriate for the local vulnerability context (Campbell, 2013; Hahn et al., 2009; Shah et al., 2013). The indexing approach involved standardizing scores using minimum and maximum values from the population sample (Hahn et al., 2009). The varied use of components and the standardization of scores limit the ability to compare results across studies, unless studies employ the same methods (Hahn et al., 2009). This study used several of the same components and methods of the Campbell (2013) study with a similar population in Jamaica, providing an opportunity for comparison (Table 8).

Table 8

Comparison of Bluefields LVI Scores and Average LVI Scores from Four Communities in St. Elizabeth, Jamaica

LVI Secondary Component	Bluefields LVI Score	St Elizabeth LVI Scores[a]
Percent of female-headed households	.20	.16
Percent of households in which no member has off-farm employment	.31	.47
Percent of households dependent solely on agriculture as a source of income	.28	.26
Percent of farmers who operate independently	.40	.46
Percent of households lacking access to assistance from outside community	.68	.43
Percent of households without any member in any community group or organization	.53	.63
Percent of farmers not owning farmland	.70	.14
Percent of farmers not having access to additional farmland	.05	.33
Percent of farmers primarily dependent on rainfall	.87	.45
Percent of households dependent on farm for food	.88	.34
Percent of farmers having trouble obtaining planting material	.73	.48
Percent of farmers who do not practice drought mitigation	.40	.28
Percent of farmers taking more than six months to restore production levels	.38	.47
Percent of farmers who never received assistance from RADA following a weather-related crop failure	.88	.49

Note. [a] The average LVI scores for St Elizabeth communities were determined from data in Campbell (2013).

Bluefields exhibited greater vulnerability in nine of the 14 secondary components that lend themselves to direct comparison with Campbell's (2013) results. Secondary components differing most (based on non-statistical comparisons) in LVI scores between Bluefields and the St Elizabeth communities studied by Campbell (2013), were in (a) land ownership; (b) dependence on rainfall; (c) dependence on farm for food; and (d) receiving assistance from RADA after a weather-related crop failure. Bluefields farmers had the higher vulnerability score for each of these secondary components. St. Elizabeth parish has high soil fertility, commercial farming, and has been referred to as Jamaica's breadbasket (Jamaica Observer, 2014) because of high agricultural productivity. These characteristics may have contributed to lesser dependence on farms for food, more assistance from agricultural extension, the ability to invest in irrigation, and a higher rate of land ownership in St. Elizabeth.

Many of the untenured farmers in Bluefields are growing crops on a large tract of land belonging to the Urban Development Commission (UDC), a government-owned corporation that plans and develops urban and rural areas in Jamaica. Many Bluefields farmers have been on UDC land for decades. Though farmers have been able to grow crops rent-free, their plots offer no collateral to invest in improved technology and they are subject to displacement when the UDC begins the process of developing the land for other purposes. The displaced farmers will have to either move to more marginal lands or seek alternative livelihoods. The threat of displacement caused by man or nature has not been investigated in this or previous LVI studies, but could be an important factor for untenured farmers in communities like Bluefields.

This Bluefields LVI study did not examine gender-based differences in vulnerability because of an inadequate sample size. However, Shah et al. (2013) examined vulnerability differences between male and female farmers in Trinidad and Tobago. Shah et al's (2013) results showed very minimal difference between men and women farmers in overall vulnerability. However, Shah et al. (2013) found significantly greater vulnerability in female-headed households for members requiring dependent care, lower than average agricultural livelihood development index scores, and being more dependent on hunting and fishing for income. Gender-based comparisons should be included in future LVI studies to because program responses need to account for differential vulnerability faced by men and women farmers (Shah et al., 2013).

PRACTICAL APPLICATIONS

Hahn et al. (2009) developed the LVI approach primarily for development planners to study vulnerability at the community level and design targeted programs. Areas of elevated vulnerability warranting intervention in Bluefields have been discussed in this chapter. This study can be conducted in the future to measure longitudinal changes in Bluefields' vulnerability. Governmental and non-governmental organizations (NGOs) in Jamaica could also employ the LVI approach before and after a developmental program to measure program impact. The LVI is also commonly applied to compare vulnerability between communities (Hahn et al., 2009; Campbell, 2013, Shah et al., 2013), but because Jamaica often organizes its communities by sub-districts, LVI could also be used to measure differences within communities (Hahn et al., 2009).

A simple form of sensitivity analysis can also be used to predict changes in vulnerability with these data. For example, if an intervention is designed to increase the use of improved agricultural technology and rainwater harvesting by a certain degree, development planners could alter these LVI scores to reflect this change. The increased use of improved agricultural technology and rainwater harvesting would reduce the overall LVI-IPCC score accordingly. Development planners would then be able to predict the potential impact of their intervention on vulnerability in Bluefields based on the change in the LVI-IPCC score. However, the validity of using these data for sensitivity analysis would degrade over time as changes occur in the vulnerability of farmers in Bluefields.

STUDY LIMITATIONS

A limitation of this study was relatively small sample size. Had additional time and resources been available, it would have been beneficial to conduct a census of the entire sample frame (N = 112). A larger sample size could have provided the ability to compare results between categories in the sample such as gender. Increasing the number of participants could have also improved the internal reliability of the instrument.

The LVI instrument is limited in the ability to generate data that can be used by other researchers for vulnerability research. This limitation exists because of the low internal reliability that results from using dichotomous variables. Employing interval variables in the place of dichotomous variables would increase reliability and generalizability, but also better capture nuances in the lives of low-income farmers.

Factors affecting low-income households in the developing world are local, complex, diverse, dynamic, and unpredictable (Chambers, 1997) and compound the challenges of using this type of index approach for comparisons of vulnerability across communities, regions, or countries. In Jamaica, for example, Campbell (2013) determined 86.5% of farmers in his study owned the land they farm whereas this study concluded just 30% of Bluefields farmers owned theirs.

There is likely a difference in how tenured farmers and untenured farmers view availability of additional land. A tenured St. Elizabeth farmer may make his or her determination based on whether or not additional farmland is available for lease or purchase, whereas the untenured farmer in Bluefields may see land as available for cultivation without consideration for the need to lease or purchase that land. This difference in perception could explain the difference in scores for access to additional farmland between farmers in this study and those in the Campbell (2013) study. Thirty-three percent of farmers in the four communities examined by Campbell (2013) reported not having access to enough farmland compared to just 5% of Bluefields' farmers.

The researcher could have mitigated this possible perception issue by employing a mixed-method approach similar to Campbell's (2013) study. Using qualitative methods such as focus groups to better understand how farmers perceive vulnerability factors could have contributed to better instrument design.

Studies that use index scores derived from the aggregation of equally weighted factors are limited by relying on the assumption each factor is of equal importance (Eakin & Borjorquez-Tapia, 2008; Hahn et al., 2009; Shah et al., 2013; Vincent, 2007). This oversimplification of reality has led some to apply methods of research aimed at determining a weight for each factor based on local conditions. For example, Eakin and Borjorquez-Tapia (2008) used a methodology using multicriteria decision analysis (MCDA) and fuzzy logic to determine weights for vulnerability factors. Participatory rural appraisal (PRA) techniques (Chambers, 1994) such as matrix ranking and scoring (Narayanasamy, 2009) could also be used to empirically derive weights with community input. The use of PRA may be more appropriate than MCDA in areas where little or no baseline data exists.

RECOMMENDATIONS FOR FUTURE RESEARCH

The validity and reliability of future LVI studies should be enhanced with more interval scale responses to fully capture degrees of vulnerability. For example, increased use of interval scale variables could measure important differences between those who harvest sufficient water to sustain full production, those who harvest inadequate amounts of water, and those who harvest zero water. Additionally, the low number of variables representing the LVI-IPCC constructs of exposure, sensitivity, and adaptive capacity limited the ability to achieve an acceptable coefficient of reliability. Careful attention should be given to improving the reliability of each construct in future LVI studies.

Shah et al. (2013) suggested attitudes and values could be incorporated as additional LVI components in the index. Hahn et al. (2009) intended the LVI to be an "accessible" tool for a wide set of users. Adding variables with attitudinal scales would enhance the ability to measure perceptions and beliefs without taking away from the ease of use intended by the LVI developers (Hahn et al., 2009).

The LVI approach is an effective method to index levels of exposure, sensitivity, adaptive capacity, and, ultimately, vulnerability in a community. However, the LVI approach fails to assess attitudes, beliefs, and values as it pertains to farmers, their practices, and how they interpret vulnerability to climate change. It will be important for future research to identify levels of vulnerability, but also to study how farmers perceive their ability to respond through adaptation. Through the combination of the LVI and qualitative assessments of vulnerability, change agents will be better informed about how to assist farmers with decisions to adopt technologies for climate adaptation (Campbell, 2013). Incorporating qualitative methods expands the original scope of the LVI approach, but can create important new knowledge about vulnerability.

One possible way to combine the LVI with a qualitative approach is to incorporate Smit and Wandel's (2006) *participatory vulnerability assessment* (PVA) framework. The LVI and PVA both are designed to identify areas where interventions to reduce vulnerability are needed (Hahn et al., 2009; Smit & Wandel, 2006). Researchers could investigate effective ways to integrate PVA and LVI to generate data that provides rich description (Creswell & Miller, 2000) and data that are quantifiably measureable over time. This type of mixed-method research would be especially useful to policy makers who need to measure the impact of their programs and policies.

Adopter segmentation studies are useful for identifying audiences to target for the adoption of technologies (Smith & Findeis, 2013). Influencing the adoption of preventive measures may be improved through targeting influential persons with trusted opinions (Rogers, 2002). Therefore encouraging the adoption of technology that will prevent crop losses caused by climate change may also require understanding the characteristics of those who adopt them. Studies that identify categories of climate change adaptation adopters and examine relationships between these adopter categories and vulnerability should be conducted. Results would provide important insights into the role innovativeness plays in vulnerability to climate change and improve the rate of adoption of adaptive technologies.

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